Title

One Health in food safety and security education: Subject matter outline for a curricular framework.

Authors

Angelos, John A
Arens, Amanda L
Johnson, Heather A
et al.

Publication Date

2017-06-01

DOI

10.1016/j.onehlt.2017.04.001

Peer reviewed

One Health 3 (2017) 56–65

Contents lists available at ScienceDirect

One Health

journal homepage: www.elsevier.com/locate/onehlt

One Health in food safety and security education: Subject matter outline for a curricular framework

John A. Angelos*, Amanda L. Arens, Heather A. Johnson, Jessica L. Cadriel, Bennie I. Osburn

Western Institute for Food Safety and Security, University of California – Davis, 1477 Drew Ave., Suite 101, Davis, CA 95618, United States

ARTICLE INFO

Keywords:
One Health
Food safety
Food security
Curriculum
Education
Subject matter
Environment
Ecosystems

ABSTRACT

Educating students in the range of subjects encompassing food safety and security as approached from a One Health perspective requires consideration of a variety of different disciplines and the interrelationships among disciplines. The Western Institute for Food Safety and Security developed a subject matter outline to accompany a previously published One Health in food safety and security curricular framework. The subject matter covered in this outline encompasses a variety of topics and disciplines related to food safety and security including effects of food production on the environment. This subject matter outline should help guide curriculum development and education in One Health in food safety and security and provides useful information for educators, researchers, students, and public policy-makers facing the inherent challenges of maintaining and/or developing safe and secure food supplies without destroying Earth's natural resources.

One sentence summary

A subject matter outline was created to accompany a One Health in food safety and security curricular framework.

One Health approaches are necessary for solving complex societal challenges and problems [1–4]. The ability for agricultural systems in high income and low- to middle-income countries to successfully feed an anticipated 9 billion people by 2050 without destroying Earth's finite resources represents one such complex societal challenge. Indeed, the challenge of establishing and maintaining food safety in today's global markets has been characterized as a complex problem that lacks easy or straightforward solutions and one that will require a One Health approach [5]. According to the 1996 Rome Declaration on World Food Security and World Food Summit Plan of Action, “Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life” [6]. While global demands for safe and sustainable sources of food are greater now than they were in 1996 when this declaration was developed, the problems associated with achieving safe and secure food supplies remain extremely complex. The large variety of diverse factors that impact production and distribution of safe food supplies including availability of natural resources, healthy ecosystems, market globalization, climate change, political instability, and poverty all underscore the need to address these issues using a One Health approach. Creatively solving problems in these and other areas will require an educated workforce that acknowledges the utility of problem-solving that considers not only an isolated problem, but also upstream factors related to a particular problem. Fortunately, recent interest in the concept of One Health has gained traction throughout the world [7–9] and international forums now exist to assist interdisciplinary groups find solutions to health challenges both locally and globally [10]. Such transdisciplinary approaches to solving problems surrounding food safety and security will be essential for sustainably meeting current and future demands for safe and secure food supplies [11].

To help address needs for an educated workforce trained not only in traditional food safety, security, and public health, but also in other areas including food production, sustainable practices, and ecosystem health, we developed a One Health in food safety curricular framework [12]. That framework grouped food safety/security content into two areas: 1) food safety/security foundations; and 2) food safety/security leadership and management. Major topics were defined within these areas and within each major topic we defined a concept statement that broadly defined student learning objectives in a particular topic. To our knowledge, this framework was the first of its kind for guiding education and training in food safety and security that embraced a One Health approach.

In this manuscript we describe subject matter for each major topic in that curricular framework as well as major themes to be addressed by a One Health Core that spans the awareness and leadership/management sections of the framework. We anticipate that this information will serve as a useful guide for educators tasked with teaching students

* Corresponding author.
E-mail address: jaangelos@ucdavis.edu (J.A. Angelos).

http://dx.doi.org/10.1016/j.onehlt.2017.04.001
Received 13 January 2017; Received in revised form 14 April 2017; Accepted 25 April 2017
Available online 26 April 2017

Table 1
Major topics, subtopics, concept statements, and subject matter for food safety/security foundations. See end of table for abbreviations.

Major topic	Subtopic	Concept statement (learning objectives)	Subject matter
Local and Global Food and Feed Supply and Safety	Global Food Supply	Students have knowledge about global food supply chains, including the effects that human populations, the environment, politics and international relations can have on food supply, demand, security, and safety	• Changes in global population growth over time • Current and projected world food demands • International food trade • Interdependence of modern civilization on global food production and trade • Food systems sustainability to meet global food demands • Challenges to food and feed production in different parts of the world • Environmental changes affecting food/feed sources and food/feed safety • Effect of politics and international relations in global food and feed trade
Local and Global Food and Feed Supply and Safety	Regulatory Oversight of Food & Feed Safety	Students know an overview of the regulatory bodies and food/feed safety regulations that govern local and global food/feed safety and contemporary issues that shape development of these standards	• Types of foods and domestic oversight by regulatory bodies, domestically (e.g., meat and poultry, milk and dairy, eggs and egg products, produce, processed foods, seafood, domestic vs imported foods) • Regulatory bodies/organizations that oversee national and international food safety laws and standards (e.g. Codex Alimentarius; EC; EFSA; FAO; FDA; FSIS; ISO; OIE; USDA; WHO) • Role of regulatory bodies in governing global food trade • Role of regulatory bodies in overseeing national and international food safety standards • International food safety regulations created by regulatory bodies/ organizations • Regulations (national and international) that help ensure production and sale of safe animal feeds (including feed ingredients, mixed feed, medicated feed, pet food and pet treats) • Actions by regulatory bodies to keep food safe during storage, shipment, and domestic/international transport (e.g., FDA, USDA/FSIS, FSMA) • Effects of global population trends, economic and environmental changes, and cultural diversity in shaping food safety regulations • Challenges to development and implementation of food safety standards in developing economies
Food- and Waterborne Illness: Sources & Prevention	Food- and Water-borne Illnesses	Students know the causes of food- and waterborne illnesses and resulting public health impacts	• Definition of food- and waterborne illnesses • Public health impact of food and waterborne illness worldwide • Microbes (including bacteria, parasites, viruses, prions and fungi) and microbial products that cause food- and waterborne illnesses • Sources of microbes that cause food- and waterborne illnesses • Chemicals and toxins and sources of chemicals and toxins that cause food- and waterborne illnesses • Types of water contamination (microbial, chemical, radiation, toxic) • Impact of different types of water contamination on food safety • Risks for foodborne illness associated with different food types • Role of different food preparation and food storage practices in causing and preventing foodborne illness • Foodborne illnesses associated with pet foods • Association between contaminated animal feed sources and foodborne illness • Growth and survival mechanisms of microbes that impact food safety (e.g. biofilms, spores, cysts, extremophilic species)
Food- and Waterborne Illness: Sources & Prevention	Public Health	Students know public health principles related to identifying, sourcing, and preventing causes of food- and waterborne illnesses	• Fundamental principles of epidemiology • Fundamental principles of biostatistics • Importance of environmental health in public health • Importance of community health in public health • Importance of community health education • Fundamental principles and methods of food- and waterborne illness and food pathogen surveillance to identify, investigate, and respond to public health threats • Principles and methods of food- and waterborne outbreak investigation and response
Food- and Waterborne Illness: Sources & Prevention	Health & Hygiene	Students know principles of human health and hygiene for preventing and mitigating food- and waterborne illness and of the role of food sources, storage practices, and preparation in affecting risks for developing food- and waterborne illnesses	• Basic hygiene practices to ensure human health • Role of hygiene in preventing foodborne illness • Role of hygiene in food preparation to prevent foodborne illness • Role of hygiene in food storage to prevent foodborne illness • Regulatory oversight of hygiene practices • Cultural/social influences on food source types, food preparation methods, and food storage methods as these relate to food safety (examples include: Bush meat, sushi, fresh salads, refrigeration, etc.)
Food- and Waterborne Illness: Sources & Prevention	Sanitation & Dis-infection	Students know principles of sanitation and disinfection for preventing food- and waterborne illnesses that can be used on the farm, in the processing plant, and in retail establishments	**General:** • Types of agents used for food and water sanitation and disinfection • Methods of food and water sanitation and disinfection • Regulations regarding pre- and post- harvest sanitation to help ensure food safety • Principles of proper cleaning and disinfection on different types of surfaces • Waste disposal methods to promote food safety

(continued on next page)

Table 1 *(continued)*

Major topic	Subtopic	Concept statement (learning objectives)	Subject matter
			• Quality assurance practices to ensure proper sanitation/disinfection **On-farm:** • On-farm sanitation practices to prevent foodborne illness • On farm pest control methods to promote food safety • Regulatory oversight on farms to prevent foodborne illness **Processing plant:** • Processing plant sanitation practices to prevent foodborne illness • Processing plant pest control practices to promote food safety • Regulatory oversight in processing plants to ensure proper sanitation and disinfection **Retail establishment:** • Retail sanitation practices to prevent foodborne illness • Retail establishment pest control practices to promote food safety • Regulatory oversight in retail establishments to ensure proper sanitation and disinfection
Food- and Waterborne Illness: Sources & Prevention	Food & Feed Adulter-ation and Contamination	Students know types of food and feed adulterants and contaminants and methods to detect and prevent food adulteration and contamination	• Types of adulterants and contaminants in food (including food additives, microbes, toxins, physical agents) • Types of adulterants and contaminants in feed • Bacteria considered as adulterants in meat products • Detection of adulterants and contaminants • Use of risk-based strategies to optimize detection, investigation, response, and prevention of foodborne illnesses • Strategies to prevent food adulteration and contamination • Strategies to prevent feed adulteration and contamination • Allergens as threats to food safety • Food additives as adulterants and contaminants • Regulatory oversight to prevent food and feed adulteration and contamination
Food- and Waterborne Illness: Sources & Prevention	Pre- and Post-Harvest Food Safety	Students know pre- & post-harvest practices including good agricultural practices (GAPs) & good manufacturing practices (GMPs) to reduce contamination of food and the risk of foodborne illness	**General pre-harvest practices:** • Pre-harvest practices to control threats from foodborne illnesses • Pre-harvest monitoring of food for contamination • Regulatory oversight of pre-harvest practices to prevent foodborne illness **General post-harvest practices:** • Post-harvest practices to control threats from foodborne illnesses • Post-harvest monitoring of food for contamination • Regulatory oversight of post-harvest processing to prevent foodborne illness **Retail practices:** • Retail establishment practices to control threats from foodborne illnesses • Retail establishment monitoring to promote food safety • Regulatory oversight of retail establishments to ensure safety of food for consumers **Web of causation:** • Role of environmental factors in causing food contamination • Role of farm practices in causing food contamination • Sources and routes of food contamination on the farm • Relationships between humans, animals, and the environment in pre-harvest food safety **GAPs:** • Definition of GAPs • Role of GAPs in food safety and preventing foodborne illness • Importance of water quality in maintaining GAPs **GMPs:** • Definition of GMPs • Role of GMPs in food safety and preventing foodborne illness
Food- and Waterborne Illness: Sources & Prevention	Food Safety Diagnostics	Students know about classical and modern methods for diagnosing food- and waterborne illnesses and how national databases are used for managing outbreaks of food- and waterborne illnesses	• Sampling methods to detect food- and waterborne pathogens • Detection of foodborne pathogens using classical, whole genome sequencing, and metagenomic methods • Linking clinical isolates collected from ill patients with pathogens detected in foods and environmental samples • National databases and use of these databases to document and coordinate responses to outbreaks of food- and waterborne illnesses • Use of social media to identify potential outbreaks of foodborne illnesses
Food- and Waterborne Illness: Sources & Prevention	Tissue Residues & Antibiotic Resistance	Students know how and why antibiotics are used in	• Similarities and differences between the antibiotic classes used in humans and animals

(continued on next page)

Table 1 *(continued)*

Major topic	Subtopic	Concept statement (learning objectives)	Subject matter
		animals, the roles and responsibilities of veterinarians under legislation, and of the impacts that antibiotics can have on human health and food safety including the development of antibiotic resistance and tissue residues	• Roles of antibiotics used in humans, animals, and human food production • Regulatory monitoring for the presence of antibiotics in food and feed sources • Regulatory oversight of antibiotics used in animals • Testing for antibiotics in food and feed sources • Concept of medically-important and prohibited drugs/drug classes in food producing animals • Non-medical uses of antibiotics • Roles and responsibilities of veterinarians and veterinary oversight to help ensure appropriate antibiotic use (e.g. changing regulations in the USA) • Effects of antibiotic residues on human and environmental health • How antibiotic resistance develops • Effects of antibiotic resistance on human and animal health and food safety • Alternatives to antibiotics used in food producing animals including probiotics
Food- and Waterborne Illness: Sources & Prevention	Emerging, Zoonotic & Regulatory Diseases	Students know about emerging diseases, zoonoses, and diseases of regulatory importance that affect public health, food safety, and food security including risk factors for emerging/zoonotic diseases, the role that food and feed have in the spread of these diseases, and methods to prevent spread	**Emerging diseases:** • Sources of emerging pathogens • Risks for spread of emerging pathogens • Culture/customs that increase risks of pathogen transmission • Role of food in spread of emerging pathogens • Role of feed in spread of emerging pathogens **Zoonotic diseases:** • Diseases and the origins of diseases that are transmitted to humans from food and water • Zoonotic disease threats to food safety including bacterial and viral diseases and prions • Interface of human-wild animal-domestic animal interface in promoting spread of zoonotic diseases • Environmental factors related to emergence of zoonotic diseases • Social/cultural factors related to development of zoonotic diseases • Concept of shared microbiomes in animals and people • Prevention of food- and waterborne zoonotic diseases • Impact of modern livestock production practices on waterborne illness • Farm practices to reduce threats of zoonotic diseases via food and water • Regulatory oversight to prevent spread of zoonotic diseases via food and water **Foreign/reportable animal diseases:** • Diseases of animals (including animals, fish, shellfish) that affect food trade • Diseases of animals (including animals, fish, shellfish) that affect food security • Pre- and Post-harvest practices to decrease spread of diseases among trading partners • Regulatory oversight to prevent introduction and spread of foreign/reportable animal diseases **Foreign/reportable plant diseases:** • Diseases of plants that affect food trade • Diseases of plants that affect food security • Post-harvest practices to reduce spread transferring foreign/reportable plant diseases among trading partners • Regulatory oversight to prevent introduction and spread of foreign/reportable plant diseases **Mitigating and preventing spread of disease:** • Pre- and postharvest methods to prevent disease introduction/spread from animals to humans and between animals and between plants including vaccination, genetic manipulation, preventing exposure, surveillance, and application of biosecurity/biocontainment principles
Food Security	Threats to Food Availability	Students know about factors that threaten food supplies or that restrict access of human populations to food and methods to prevent food insecurity	**General:** • Principles of establishing food security as described by the FAO Rome Declaration on World Food Security and World Food Summit Plan of Action • Factors that threaten availability of food (natural and man-made) including wastage/spoilage • Factors that affect access to food (poverty, economics, animal disease) • Consequences of food insecurity (poverty, hunger, malnutrition) • Prevention of food insecurity in developed and developing economies • Strategies to establish, maintain, and monitor global food security • Concept of yield gaps and methods to close yield gaps

(continued on next page)

Table 1 *(continued)*

Major topic	Subtopic	Concept statement (learning objectives)	Subject matter
			• Factors affecting food affordability **Food defense/agroterrorism/emergency preparedness:** • Concept of food defense • Development and implementation of food defense plans • Identifying potential targets of agroterrorism • Mitigating threats of agroterrorism • Emergency planning for intentional and unintentional acts that threaten food safety and security • Concept of incident command structure • Concept of local/community planning to minimize dangers posed by natural or intentional acts to food availability • Concepts of biosecurity and biocontainment during a foreign animal disease outbreak
Food Production	Animal & Plant Production	Students know standard and alternative plant and animal-origin food production practices and the effects that certain production practices have on food safety	**Produce:** • Overview of modern produce farming practices (includes leafy greens, fruits, nuts, and grains) • Pre-harvest (e.g., growing; harvesting) practices to reduce potential threat of foodborne illness from produce • Post-harvest (e.g., packing; holding; processing) practices to reduce potential threat of foodborne illness from produce • Regulatory oversight to reduce threats of foodborne illness from produce • Produce farming methods to reduce introduction of foodborne pathogens into produce **Dairy:** • Overview of modern dairy farming methods including organic production and manure management • Types of dairy producing animals • Regulatory oversight of dairy processes to reduce threats of foodborne illness (e.g., Pasteurized Milk Ordinance; Codex Alimentarius) • Distribution of dairy products in developed and emerging economies • Animal feed as a source of foodborne disease introduction into dairy animals **Livestock:** • Overview of current livestock production practices including CAFOs, organic production and manure management • Animal feed as a source of foodborne disease introduction into livestock • Regulatory oversight of livestock processing to promote food safety **Poultry and shell egg:** • Overview of current poultry and shell egg production practices and litter management • Role of animal feed in introducing foodborne pathogens into poultry • Regulatory oversight of poultry and shell egg processing to promote food safety **Fish:** • Overview of current fish production practices in natural and man-made environments • Role of feed in introducing foodborne pathogens into fish • Regulatory oversight of fish processing to promote food safety **Shellfish:** • Overview of current shellfish production practices in natural and man-made environments • Role of feed in introducing foodborne pathogens into shellfish • Regulatory oversight of shellfish processing to promote food safety
Food Production	Genetically Modified Organisms (GMO's)	Students know about GMOs used in modern food production, food safety issues of GMOs, and of roles that GMOs may have in helping to satisfy global food supply demands	• Overview of GMOs • Traits conferred by GMOs • Role of GMOs in meeting demands for world food production • Nutritional equivalency of natural vs GMO organisms • Food safety issues surrounding GMOs • Regulatory oversight of GMOs • Regulatory oversight of global GMO trade
Food Production	Workplace Safety	Students know farm-worker safety and health hazards associated with agriculture, regulations governing farmworker safety, and management methods and strategies to promote	• Overview of types of hazards to agriculture workers including manure pits, silos, aerosols, flowing grains, fires, machinery, chemicals, and pesticides • Regulatory oversight of workplace safety • Occupational prevention tools, interventions for different hazards • Management methods and strategies to prevent hazards to agriculture workers from various sources including manure pits; silos; flowing grains; fires; machinery; chemicals; and pesticides

(continued on next page)

Table 1 *(continued)*

Major topic	Subtopic	Concept statement (learning objectives)	Subject matter
		farmworker safety	
Food Production	Animal Welfare	Students know principles of animal welfare and practices to ensure welfare of production animals	• Principles of animal welfare (including animal pain, stress, cognition, motivation, emotions, and preferences) • Environmental enrichment methods to promote agricultural animal welfare • Production practices to promote agricultural animal welfare • Assessing agricultural animal welfare • Regulatory oversight of agricultural animal welfare on farm and at harvest • Relationship between improved animal welfare and improved food safety • Cultural barriers in achieving animal welfare standards
Ecosystem	Ecosystem Contamination	Students know the role of human activity on the development of different types of environmental contamination and the consequences of contamination on ecosystem health	**Water contamination:** • Effects of water contamination (including groundwater and oceans) on ecosystem health • Flow of contaminants including nanoparticles and microplastics through water systems • Impact of modern agriculture on water quality including effects of animal waste/waste handling practices • Overview of strategies to mitigate and prevent water contamination • Effects of air pollution on water habitats (acid rain, climate change, ocean warming) • Regulatory oversight to prevent water contamination • Overview of the hydrologic cycle (precipitation, infiltration, evaporation, transpiration, surface runoff, groundwater flow) • Role of hydrologic processes in ecosystem survival including survival of humans and animals (domestic and wildlife) **Soil contamination:** • Overview of soils and soil formation • Movement of contaminants through soil • Effects of soil contamination on ecosystem health • Effects of soil contamination on food safety (animal and plant) • Types of soil contamination (microbial, heavy metal, chemical, radiation, toxic) • Impact of modern agriculture on soil contamination and quality • Effects of land exhaustion on food production • Overview of strategies to mitigate and prevent soil contamination including phytoremediation • Regulatory oversight to prevent soil contamination **Air pollution:** • Overview of effects of human and animal activity on the atmosphere (including smog, ozone pollution, ozone depletion, climate change, and acid rain) • Effects of modern agriculture on air quality • Effects of air pollution on ecosystem health including animal, human, and plant health • Overview of strategies to mitigate and prevent air pollution • Regulatory oversight to prevent air pollution
Ecosystem	Ecosystem Services	Students know the concepts of ecosystem services, planetary health, and planetary boundaries and of the impacts of human activity including food production on ecosystem health, biodiversity, strategies to minimize such impacts, and tradeoffs that are made to sustain life for the world's population	• Concept of sustainable development • Concepts of ecosystem services in the context of environmental assessments (e.g., Millennium Ecosystem Assessment) • Concepts of planetary health and planetary boundaries as these related to sustainability • Tradeoffs that must be made to produce/provide sufficient food/drinking water and energy to support the world's population while minimizing negative impacts on ecosystem services • Overview of diversity of life on earth including animal/plant/insect/microbial life on land, sea, and air • Changes to biodiversity brought about from human activity including climate change, deforestation, urbanization, salinization, and desertification • Effects on biodiversity from agriculture • Mitigating effects on biodiversity caused by human activity

Abbreviations: CAFO (concentrated animal feeding operation); EC (European Commission); EFSA (European Food Safety Authority); FAO (Food and Agriculture Organization of the United Nations); FDA (Food and Drug Administration); FSIS (Food Safety Inspection Service); FSMA (Food Safety Modernization Act); GAPs (Good Agricultural Practices); GMO (genetically modified organism); GMPs (Good Manufacturing Practices); ISO (International Organization for Standardization); OIE (Office International des Epizooties (World Organization for Animal Health)); USDA (United States Department of Agriculture); WHO (World Health Organization).

Table 2
Major topics, subtopics, concept statements, and subject matter for food safety/security leadership and management. See end of table for abbreviations.

Major topic	Subtopic	Concept statement (learning objectives)	Subject matter
Core	Agricultural Dynamic Management	Students know methods to identify current and future problems in order to design and implement effective, sustainable solutions to address problems related to animal and plant-based production agriculture, and ecosystem health	• Methods to identify current and future problems in agricultural production systems • Methods to design effective and sustainable solutions for animal and plant-based agriculture • Methods to implement sustainable solutions for animal and plant-based agriculture • Methods of training future leaders with designated responsibilities • Methods to assess team member performance • Ways to apply ADM to different sectors of plant and animal-based agriculture
Core	Risk Analysis	Students know basic principles of risk analysis, including risk management, risk assessment, and risk communication as it relates to production of safe human food and animal feed and health of ecosystems involved in such production	• Definitions of risk management, risk assessment, and risk communication • Basic components of risk analysis (risk management, risk assessment, and risk communication) as these apply to production of safe food and feed and maintenance of ecosystem health
Core	Epidemiology	Students know applications of epidemiologic principles and study design to assist in food- and waterborne outbreak investigations	• Epidemiologic approaches to quantitative research methods used in outbreak investigation • Properties of tests • Epidemiologic study design
Food & Feed	Biosecurity	Students know biosecurity principles and applications of those principles to protect food (including animal and plant) and water sources from pests and diseases that threaten food safety and security	• Use of biosecurity principles to prevent incursion and spread of pests and diseases of agricultural plants and animals • Monitoring biosecurity • Regulatory oversight of biosecurity • Risk management related to biosecurity
Food & Feed	Food Safety Plans	Students know components of food safety plans including the Hazard Analysis Critical Control Point (HACCP) approach to identifying, evaluating, and controlling hazards to human food and animal feed and know how to write food safety and HACCP plans	• Good Agricultural Practices (GAPs) • Food Safety Plans (e.g., FSMA/FSIS in USA) • HAACP approach to identifying, evaluating, and controlling hazards to all types of food and feed production • Components of a HACCP system, HACCP plan, and HACCP team • Writing food safety and HAACP plans for different types of food and feed production
Food & Feed	Pest Management	Students know effective management strategies for animal and plant pests and diseases and methods to manage pests and diseases that minimize risks to ecosystem health	• Pests and diseases of agricultural plants and animals that affect food security and food safety • Management strategies for pests and diseases affecting agricultural animals • Management strategies for pests and diseases affecting produce • Ecosystem health risks associated with different management strategies for animal and plant pests and diseases • Strategies to effectively manage plant and animal pests and diseases without harming ecosystems
Food & Feed	Sanitation & Disinfection	Students know sanitation control strategies, practices, monitoring, and regulations in pre- and post-harvest food production to prevent foodborne illnesses	• Sanitary control processes for food processing plants including water treatment, temperature control, chemical and physical sanitizing agents, and building design • Regulatory oversight of sanitation control during pre- and post-harvest food production • Sanitary methods for pest control • Sanitary methods for disposal of wastes associated with food processing • Regulatory oversight of processing plant sanitary control • Methods for monitoring quality assurance of sanitary control measures
Food & Feed	Feed Manufacturing	Students know animal feed manufacturing processes, regulations, and testing practices and roles of these processes, regulations, and testing practices in helping to ensure feed and food safety.	• Basics of animal feed manufacturing methods • Methods for maintaining animal feed safety during feed manufacturing • Regulatory oversight of animal feed manufacturing to maintain feed safety • Roles of feed manufacturing regulators in assuring feed safety • Sampling to detect feed contamination • Impact of feed safety on food safety
Agriculture & Ecosystem	Ecosystem Monitoring	Students know methods for monitoring ecosystem health to prevent contamination of food and feed and illness in humans and animals (wild and domestic), and for monitoring the impacts of	• Methods to monitor ecosystem health including monitoring of land, water, air, and measuring climate change to quantify effects of human activity related to food production as it relates to sustainable development • Role of ecosystem monitoring in preventing contamination of food and feed (including chemical contamination) • Role of ecosystem monitoring in preventing illness in humans and animals (wild and domestic)

(continued on next page)

Table 2 *(continued)*

Major topic	Subtopic	Concept statement (learning objectives)	Subject matter
		food production practices on ecosystem health	• Regulatory oversight of farms to prevent ecosystem contamination (e.g., well monitoring around dairies; regulations governing lagoons)
Agriculture & Ecosystem	Water & Waste Management	Students know methods and system design for treatment, disposal, and utilization of wastes associated with food and agricultural production and methods to mitigate ecosystem contamination	• Types of wastes generated from animal and crop production and processing • Unsafe waste disposal practices that threaten ecosystem health and a safe food supply • Application of methods to mitigate and prevent water contamination • Application of natural methods to mitigate and prevent soil contamination including phytoremediation (phytoextraction; rhizofiltration; phytostabilization) for heavy metal soil contamination • Safe methods and systems to treat, dispose of, and/or utilize generated solid wastes including composting methods • Safe methods and systems to treat, dispose of, and/or utilize generated waste water including uses of grey water and sewage treatment • Novel methods for waste management (e.g. microbial treatments) • Regulatory oversight of waste handling methods and waste mitigation practices including composting and water treatment • Application of methods to mitigate and prevent air pollution
Agriculture & Ecosystem	Impact Assessment	Students know how to conduct environmental impact assessments, about the use of impact assessments in shaping public policy, and development of methods to adapt to ecosystem health changes brought on by human activities	• Methods for conducting environmental impact assessments including assessments of waterways • Types of information used in generating environmental impact statements • Use of findings from environmental impact assessments in shaping public policy related to food safety and agriculture • Development and application of practices and strategies to adapt to ecosystem changes including climate change
Agriculture & Ecosystem	Habitat Conservation	Students know ecological issues and controversies surrounding loss of species and habitats on land and in water and the impacts of modern agriculture on natural habitats and methods to mitigate these impacts	• Definition of habitats on land and in water • Effects of industrialization on habitats including loss of biodiversity • Effects of modern agriculture on habitats • Environmental conservation to preserve natural habitats • Farming methods to reduce impacts of modern agriculture on habitats
Agriculture & Ecosystem	Sustainable Agricultural Practices	Students know methods to conserve resources while supporting demand for increasing food and feed production for a growing global population	**General:** • Sustainability science • Concept of sustainable development • Demands for resources imposed by human populations, industrialization, and modern agriculture • Methods for effectively utilizing resources to meet needs for animal feed and human food production while maintaining ecosystem health **Sustainable agriculture:** • Definition of sustainable farming • Sustainability of different agricultural systems and farming practices • How to meet needs for animal feed and human food production through sustainable farming practices • Threats to sustainable farming practices **Precision agriculture:** • Farming practices to optimize fertilizer use • Farming practices to optimize pesticide use • Farming practices to optimize water use • Use of precision agriculture to reduce environmental impacts of modern agriculture
Food & Society	Poverty and Food	Students know the relationship between poverty and food safety and security, the causes and effects of regional and global poverty, and strategies to reduce poverty through improved food safety and security	• Analysis of the relationship between local and global poverty and food safety and security • Analysis of consequences of local and global poverty including chronic disease and malnutrition • The United Nations Sustainable Development Goals, including the eradication of poverty • Methods of reducing poverty through policies including economic growth, foreign aid, and community-level interventions • Importance of food security in mitigating poverty • Methods to reduce hunger by reducing food spoilage • Methods to reduce hunger by reducing food waste • Effects of overpopulation, overgrazing, land exhaustion, and groundwater depletion on the development and maintenance of poverty
Food & Society	Susceptible Populations	Students have knowledge of the types of populations that are most susceptible to food- and waterborne illnesses and	• Identification of risk factors that contribute to susceptibility to food- and waterborne illness in humans • Methods to reduce risks and threats of food- and waterborne illness in susceptible populations including safe food handling, storage, and cooking

(continued on next page)

Table 2 *(continued)*

Major topic	Subtopic	Concept statement (learning objectives)	Subject matter
		of risk factors and mitigation strategies to reduce susceptibility to food- and waterborne illnesses in these populations	
Food & Society	Agronomics	Students know how to apply economic theory to optimize food and fiber production and distribution while maintaining ecosystem health	• Application of economic theory to optimize production and distribution of food and fiber • Role of modern agriculture in stimulating economic development • Impacts of breaches in food safety on agricultural and economic development

Abbreviations: ADM (Agricultural Dynamic Management); FSIS (Food Safety Inspection Service); FSMA (Food Safety Modernization Act); HACCP (Hazard Analysis Critical Control Point).

Table 3
One Health core concept statement and subject matter.

Concept statement (learning objectives)	Subject matter
Students apply a One Health transdisciplinary collaborative approach to address food safety problems involving animals, humans, plants and the environment to support the establishment of safe and secure food and water supplies	• Management • Communication and informatics • Values and ethics • Leadership • Teams and collaboration • Roles and responsibilities • Systems thinking • Practical applications • Adapting to changing environments • Diversity and multicultural awareness • Critical thinking • Research methods

about food safety and security as viewed from a One Health perspective.

The organization and development of the subject matter contained in this outline came about during the process of creating our previously published curricular framework [12]. That process involved brainstorming exercises that resulted in the identification of broad categories of information that formed the basis for the published framework. As part of these exercises we also identified subjects, issues, concepts, and/or ideas related to food safety and security that we believed would be important when these categories were viewed from a One Health perspective and in the broadest-possible context. The identified subjects, issues, concepts, and ideas are presented in this subject matter outline organized with associated curricular framework subtopic and concept statements (see Table 1 and Table 2).

To illustrate subject matter in an area that has gained increased national and international attention, one may consider the topic of antibiotic resistance. A need exists for a One Health approach to address the threat of antimicrobial resistance as well as for collaborations among many professional disciplines and organizations with critical roles at the intersections of human, animal, and environmental health [13]. To help illustrate subject matter related to antibiotic resistance in this outline and how coverage of this topic tries to embrace a One Health approach, one may consider the subtopic of tissue residues in food safety/security foundations (see Table 1). The concept statement (learning objectives) for this subtopic is that students know how and why antibiotics are used in animals, the roles and responsibilities of veterinarians under legislation, and of the impacts that antibiotics can have on human health and food safety including the development of antibiotic resistance and tissue residues. Subject matter to support learning about these concepts includes (see Table 1): similarities and differences between the antibiotic classes used in humans and animals; roles of antibiotics used in humans, animals, and human food production; regulatory monitoring for the presence of antibiotics in food and feed sources; regulatory oversight of antibiotics used in animals; testing for antibiotics in food and feed sources; concept of medically-important and prohibited drugs/drug classes in food producing animals; non-medical uses of antibiotics; roles and responsibilities of veterinarians and veterinary oversight to help ensure appropriate antibiotic use (e.g. changing regulations in the USA); effects of antibiotic residues on human and environmental health; how antibiotic resistance develops; effects of antibiotic resistance on human and animal health and food safety; and alternatives to antibiotics used in food producing animals including probiotics. Coverage of these topics should help students to gain a better understanding of the challenges surrounding development and prevention of antibiotic resistance in a way that embraces a transdisciplinary One Health approach.

A key component of teaching about a One Health approach to food safety and security is the idea that students should learn to apply transdisciplinary collaborative approaches when addressing food safety problems involving animals, humans, plants, and the environment. Towards this end the outline includes One Health Core topics designed to span both foundational and leadership/management levels (see Table 3). Some of the coverage topics include: communication; values; ethics; leadership; teams and collaboration; diversity and multicultural awareness; and critical thinking. In a One Health in Food Safety curriculum we anticipate that these topics could be best taught using case examples that encourage students to work together to solve problems to help illustrate the benefits gained by collective engagement of experts in diverse fields.

Full development and delivery of this entire curriculum at one location would be an enormous, if not impossible, endeavor. The curriculum is broad and would require participation of experts across many different fields. While we previously suggested that it could be taught in a One Health in Food Safety and Security Center [12], our more recent experience suggests that portions of this curriculum might also be taught by experts at different locations through use of modern telecommunication methods. This approach could draw upon the subject matter expertise of individual teachers at the same or different institutions working together to deliver information related to specific topics in this curriculum.

This subject matter outline should be broadly applicable to different audiences in different countries as the outline avoids specifying public policy related to specific countries. To illustrate this using the above antibiotic/tissue residue example, we have not named regulations specific to any particular regulatory body and, as a result, we believe that this subject matter outline can be adapted for students in different locations throughout the world.

While we believe that this curriculum touches on many aspects of food safety and security as viewed from a One Health approach, we

realize that certain topics may have been overlooked. Moreover, advances in all of the sciences addressed by this curriculum will necessitate ongoing revision and updating of this curriculum. Our intent is that this subject matter outline will serve as a valuable resource for teachers and students who are tasked with teaching/learning about food safety and security from a One Health approach, and that over time necessary updates to this outline will be made to maintain its usefulness for students and the relevant public and private food production units, industries, governments, and communities that they serve.

Acknowledgements

We thank Rob Atwill, Xunde Li, Jim Cullor, and Marguerite Pappaioanou for reviewing and commenting on this subject matter outline. Funding support for this project was provided through the U.S. Food and Drug Administration (FDA), Cooperative Agreement 1U54FD004327 and Nanjing Agricultural University. These funding entities were not involved in the writing of this report nor in the decision to submit this work for publication.

References

[1] L.H. Kahn, B. Kaplan, T.P. Monath, J.H. Steele, Teaching "One Medicine, One Health", Am. J. Med. 121 (2008) 169–170.
[2] J. Zinsstag, E. Schelling, K. Wyss, M.B. Mahamat, Potential of cooperation between human and animal health to strengthen health systems, Lancet 366 (2005) 2142–2145.
[3] P.A. Conrad, J.A. Mazet, D. Clifford, C. Scott, M. Wilkes, Evolution of a transdisciplinary “One Medicine–One Health” approach to global health education at the University of California, Davis, Prev. Vet. Med. 92 (2009) 268–274.
[4] M.A. Barrett, T.A. Bouley, A.H. Stoertz, R.W. Stoertz, Integrating a One Health approach in education to address global health and sustainability challenges, Front. Ecol. Environ. 9 (2010) 239–245.
[5] L.J. King, One Health and food safety, in: E.R. Choffnes, D.A. Relman, A. OL, R. Hutton, A. Mack (Eds.), Improving Food Safety Through a One Health Approach: Workshop Summary, National Academies Press, Washington, D.C., 2012, pp. 218–225.
[6] Deputy Director General (Operations), Rome Declaration on World Food Security and World Food Summit Plan of Action, Available at: http://www.fao.org/docrep/003/w3613e/w3613e00.htm, (1996) (Accessed April 10, 2017).
[7] Z. Batsukh, B. Tsolmon, D. Otgonbaatar, B. Undraa, A. Dolgorkhand, O. Ariuntuya, One Health in Mongolia, Curr. Top. Microbiol. Immunol. 366 (2013) 123–137.
[8] J. Lubroth, FAO and the One Health approach, Curr. Top. Microbiol. Immunol. 366 (2013) 65–72.
[9] C. Stroud, B. Kaplan, J.E. Logan, G.C. Gray, One Health training, research, and outreach in North America, Infect. Ecol. Epidemiol. 6 (2016) 33680.
[10] C. Cardona, D.A. Travis, K. Berger, G. Coat, S. Kennedy, C.J. Steer, et al., Advancing One Health Policy and implementation through the concept of One Medicine One Science, Glob. Adv. Health Med. 4 (2015) 50–54.
[11] R. Garayoa, M. Cordoba, I. Garcia-Jalon, A. Sanchez-Villegas, A.I. Vitas, Relationship between consumer food safety knowledge and reported behavior among students from health sciences in one region of Spain, J. Food Prot. 68 (2005) 2631–2636.
[12] J. Angelos, A. Arens, H. Johnson, J. Cadriel, B. Osburn, One Health in food safety and security education: a curricular framework, Comp. Immunol. Microbiol. Infect. Dis. 44 (2016) 29–33.
[13] S.L. Lammie, J.M. Hughes, Antimicrobial resistance, food safety, and one health: the need for convergence, Annu. Rev. Food Sci. Technol. 7 (2016) 287–312.